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(54) **SWAP MUX TO RELIEVE LOGIC DEVICE
INPUT LINE STRESS**

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(57) **ABSTRACT**

Disclosed is a method an apparatus for selectively providing additional inputs into a logic block, such as a LAB of a PLD, carrying out a logic function requiring a relatively high number of inputs. A PLD in accordance with the present invention includes at least first and second LABs. A plurality of signal lines are capable of driving the second LAB and a plurality of output lines are driven by the first LAB. The PLD also includes a swap multiplexer (MUX) having a first selectable input capable of being driven by the output lines and a second selectable input capable of being driven by the signal lines. An output of the swap MUX is capable of driving the first LAB.

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(58) **Field of Classification Search** **326/37-41,**
326/47

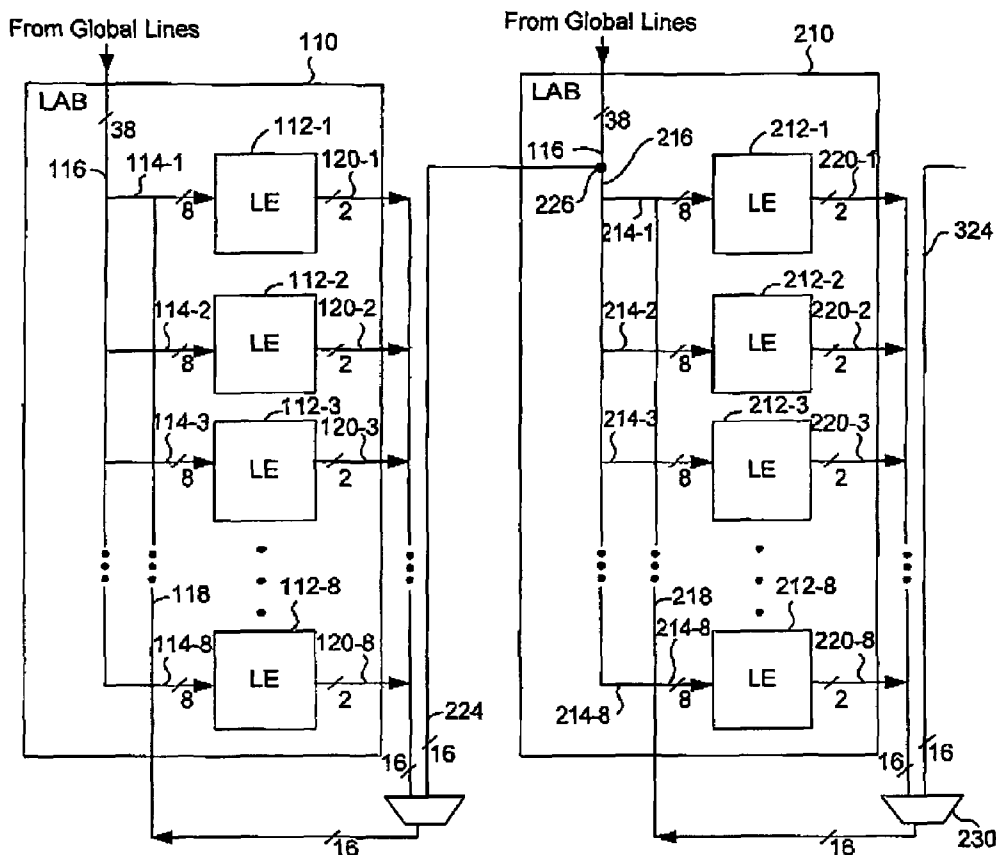
See application file for complete search history.

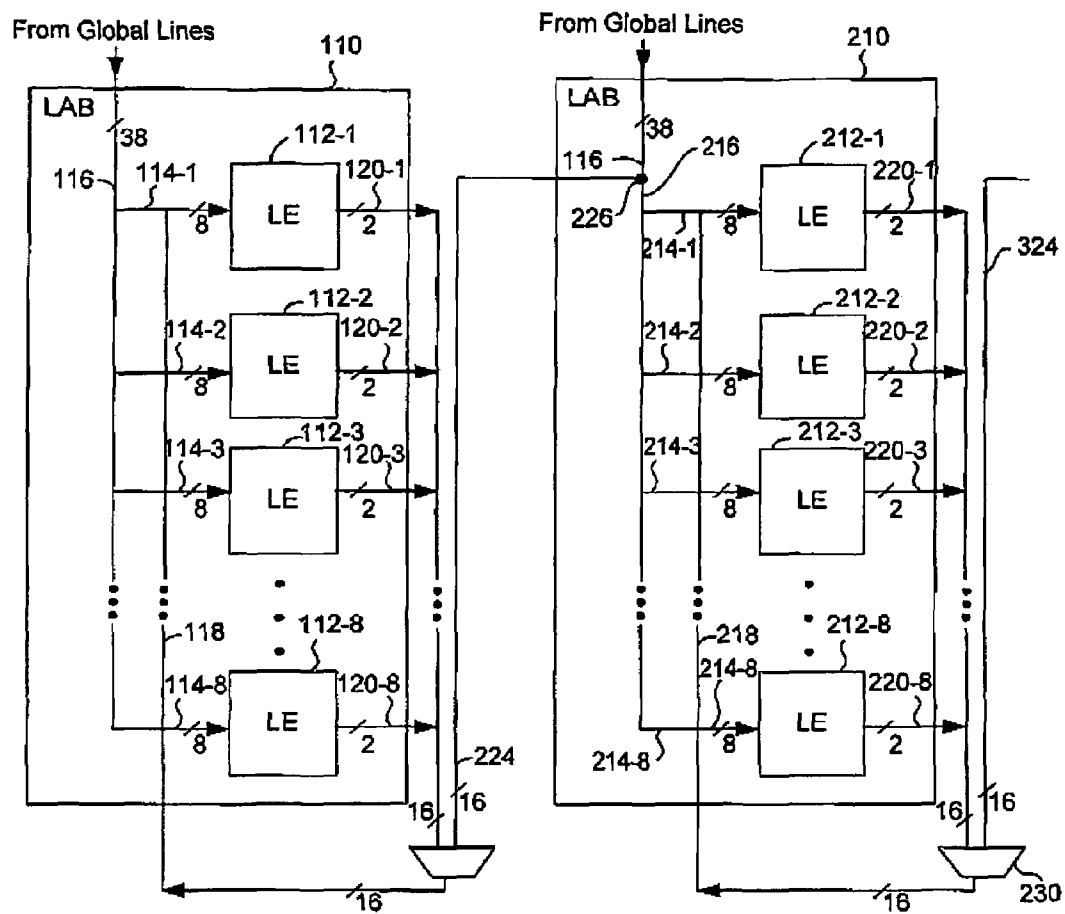
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21 Claims, 5 Drawing Sheets



**FIG. 1**

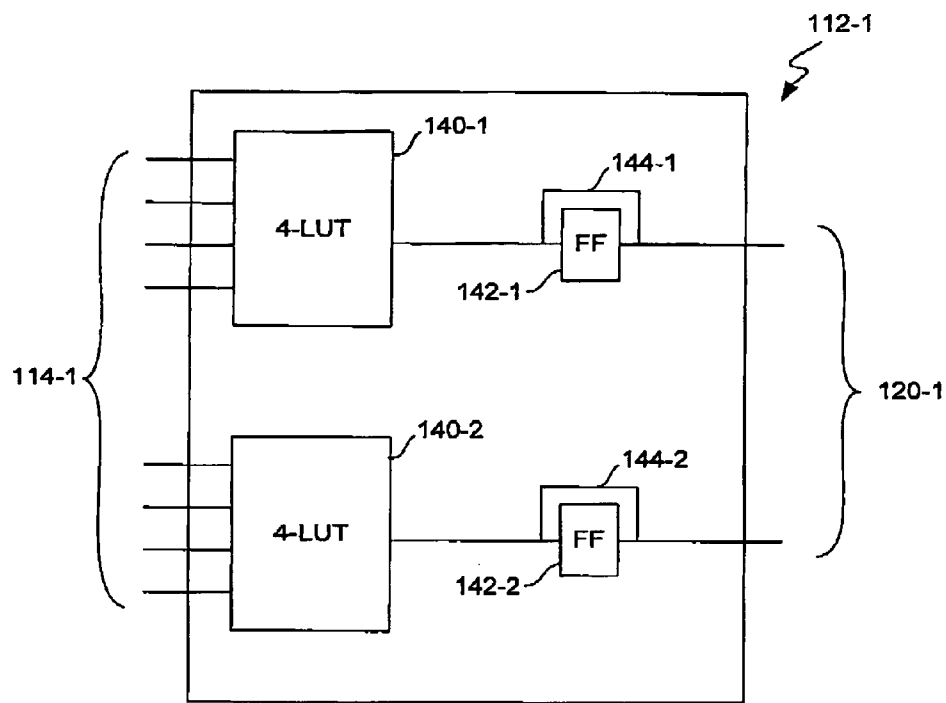


FIG. 2A

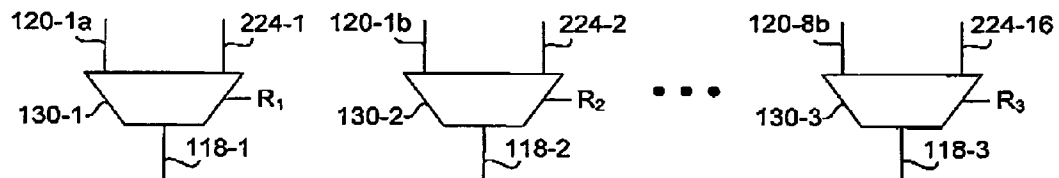
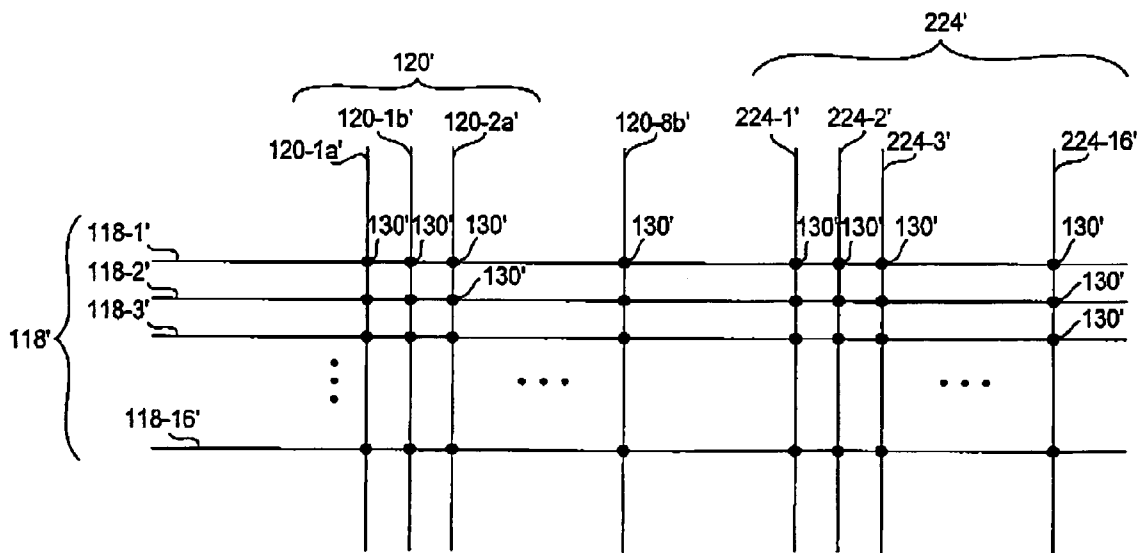
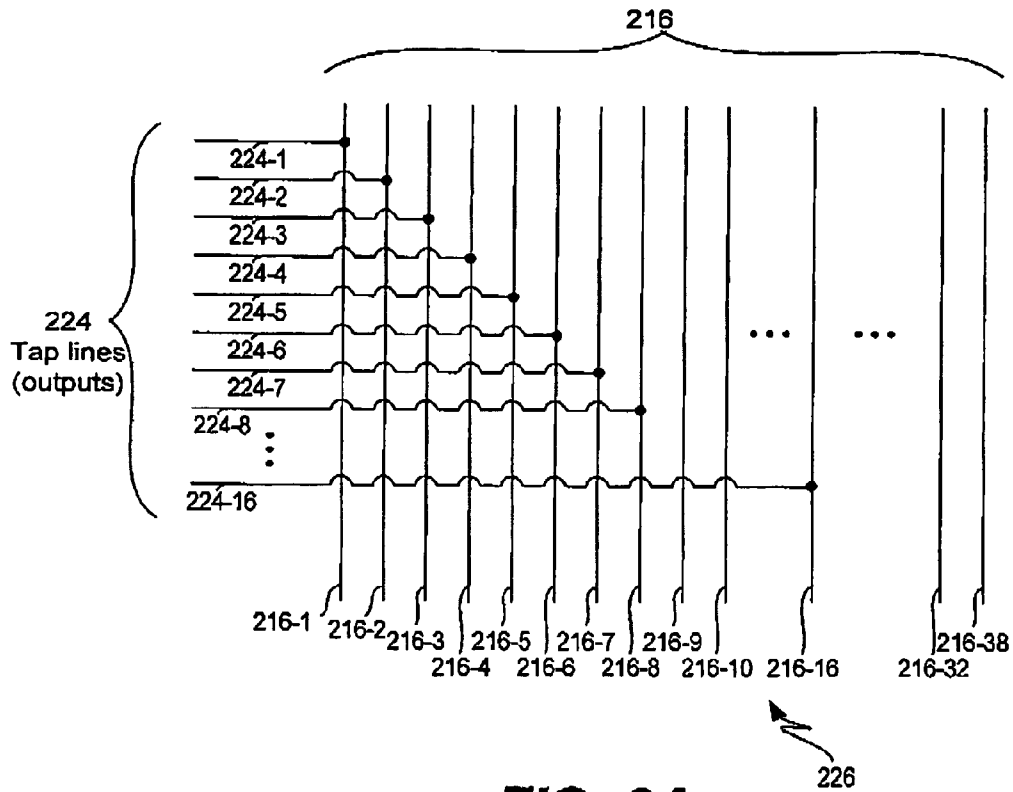


FIG. 2B



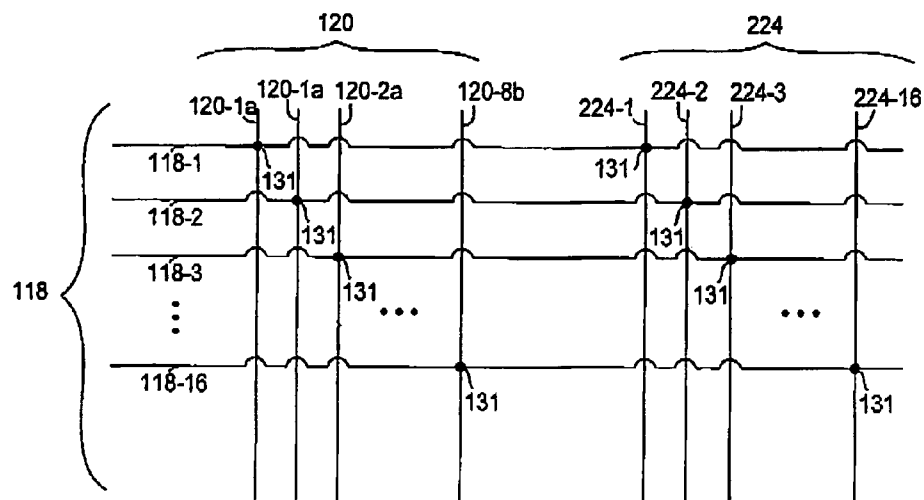


FIG. 3C

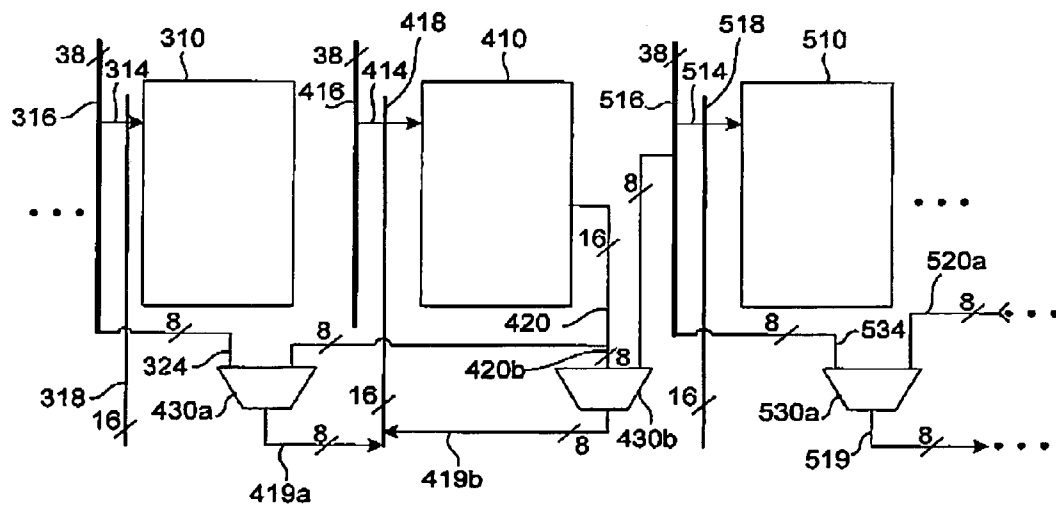
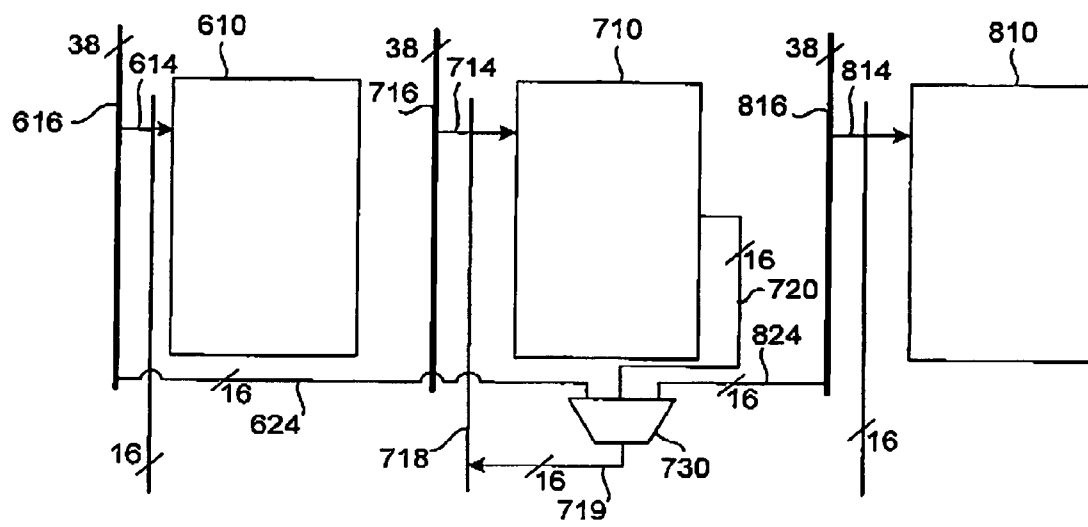


FIG. 4

300



600 ↗

FIG. 5

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SWAP MUX TO RELIEVE LOGIC DEVICE INPUT LINE STRESS

BACKGROUND OF THE INVENTION

Programmable logic devices (PLDs) (also sometimes referred to as CPLDs, PALs, PLAs, FPLAs, EPLDs, EEPLDs, LCAs, FPGAs, or by other names), are well-known integrated circuits that provide the advantages of fixed integrated circuits with the flexibility of custom integrated circuits. Such devices typically provide an “off the shelf” device having at least a portion that can be electrically programmed to meet a user’s specific needs. Application specific integrated circuits (ASICs) have traditionally been fixed integrated circuits, however, it is possible to provide an ASIC that has a portion or portions that are programmable; thus, it is possible for an integrated circuit device to have qualities of both an ASIC and a PLD. The term PLD as used herein will be considered broad enough to include such devices.

PLDs may include blocks of smaller logic elements (LEs) which typically have a number of inputs. The blocks containing LEs are sometimes referred to as logic array blocks (LABs; also referred to by other names, e.g., configurable logic blocks, or CLBs). LEs, in turn, may contain components to programmably carry out different types of logic functions. LABs containing LEs may be arranged in a two dimensional array in a PLD.

In order to input and direct logic signals to LEs, PLDs can include a number of types of signal lines. A first type of line, referred to herein as a global line, can carry signals between LABs. Other lines can be driven by global lines to carry signals into a particular LAB. These lines are referred to herein as LAB lines (LAB lines can also be referred to as logic input MUX or “LIM” lines). LAB lines typically include between 20 to 40 individual lines, though greater or fewer lines may also be included. The architecture of a LAB may also include LE output lines which can be routed back to drive the inputs of either the LE that drove the particular output or a different LE, typically within the same LAB. Thus, it is not necessary, and typically not the case, that a LAB is driven by enough LAB lines to drive every input of every LE in the LAB.

However, it is sometimes the case that a logic function which could otherwise be carried out by a single LAB cannot be because the particular logic function requires more inputs into the lab than are provided by the LAB lines. In such a case, in configuring a PLD to carry out the logic function, it may be necessary to split the logic function between two or more LABs in the PLD. Such configuration, though, can cause inefficient use of physical resources and increased timing delays.

BRIEF SUMMARY OF THE INVENTION

The present invention includes a method and apparatus for selectively providing additional inputs into a cluster of logic blocks (referred to herein as a Logic Array block or LAB) carrying out a logic function requiring a relatively high number of inputs. A PLD in accordance with the present invention includes at least first and second LABs. A plurality of signal lines are capable of driving the second LAB and a plurality of output lines are driven by the first LAB. The PLD also includes one or more swap multiplexers (MUXes) having a first selectable input capable of being driven by an output line and a second selectable input capable of being driven by a signal line. An output of the

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swap MUX is capable of driving the first LAB. In another aspect of the present invention, the first LAB of the PLD includes plurality of first logic elements (LEs) and the second LAB includes a plurality second LEs. The output lines are driven by the first LEs and the signal lines are capable of driving the second LEs. The output of the swap MUX is capable of driving the first LEs.

In another aspect of the present invention, a method of driving LABs in a PLD includes providing at least first and second LABs in the PLD. The first LAB drives a plurality of output lines and second LAB is driven with a plurality of signal lines. A first selectable input of a swap MUX is driven by the output lines and a second selectable input of the swap MUX is driven by the signal lines. The output of the swap MUX drives the first LAB.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram illustrating a portion of a programmable logic device (PLD) including a swap multiplexer (MUX) and in which a first LAB can be driven by inputs which can also drive a second LAB in accordance with the present invention;

FIG. 2a is a schematic diagram illustrating an example of the details of a logic element shown in FIG. 1.

FIG. 2b is a schematic diagram illustrating details of the swap mux shown in FIG. 1.

FIG. 3a is a schematic diagram illustrating a preferred embodiment of an interconnection between LAB lines and tap lines illustrated in FIG. 1 in accordance with the present invention.

FIG. 3b is a schematic diagram illustrating a general embodiment of a the swap MUX shown in FIG. 1 and detailed in FIG. 2b.

FIG. 3c illustrates a preferential embodiment wherein each swap MUX has only two inputs.

FIG. 4 is a schematic diagram illustrating another embodiment of a method and apparatus in accordance with the present invention including a portion of a PLD having two swap MUXes and in which a first LAB can be driven by either of two sets inputs which can also respectively drive a second LAB and a third LAB in accordance with the present invention;

FIG. 5 is a schematic diagram illustrating still another embodiment of a method and apparatus in accordance with the present invention including a portion of a PLD having a single, three input swap MUX and in which a first LAB can be driven by either of two sets of inputs which can also respectively drive a second LAB and a third LAB in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention includes a method and apparatus for selectively providing additional inputs into a logic block, such as a LAB of a PLD, carrying out a logic function requiring a relatively high number of inputs. FIG. 1 is a schematic diagram of one embodiment of a LAB architecture showing how a LAB can be selectively provided with additional input lines in accordance with the present invention. FIG. 1 shows a portion 100 of a PLD including a first LAB 110 and second LAB 210 each having 8 LEs (only 4 LEs per LAB are shown in FIG. 1). LAB 110 includes LEs 112-1 through 112-8 and LAB 210 includes LEs 212-1 through 212-8. LAB 110 and LAB 210 may also include greater or fewer than 8 LEs. LAB 110 is driven by a set of

LAB lines **116** and LAB **210** is driven by a set of LAB lines **216**. Both LAB lines **116** and LAB lines **216** are preferably driven by global lines (not shown) included in a the PLD containing first and second LABs **110** and **210**. In the example shown in FIG. 1, LAB lines **116** and **216** each preferably include 38 individual lines. It is also contemplated, however, that greater or fewer than 38 individual lines be included in each set of LAB lines **116** and **216**, in particular as the number of LEs contained in the LAB is changed.

LEs **112-1** through **112-8** of LAB **110** include a set of input lines **114-1** through **114-8**, respectively, and a set of local output lines **120-1** through **120-8**, respectively. Global outputs from the LAB are not shown. Similarly, LEs **212-1** through **212-8** of LAB **210** includes a set of input lines **214-1** through **214-8**, respectively, and a set of output lines **220-1** through **220-8**, respectively. Preferably, sets of input lines **114-1** through **114-8** and **214-1** through **214-8** each include 8 lines and sets of local output lines **120-1** through **120-8** and **220-1** through **220-8** each include 2 individual lines. It is considered, however, that greater or fewer than 8 individual lines be included in each set of input lines **114-1** through **114-8** and **214-1** through **214-8** and greater or fewer than 2 outputs be included in sets of output lines **120-1** through **120-8** and **210-1** through **220-8**.

FIG. 2a is a schematic diagram illustrating one example of an LE **112-1**. LEs **112-2** through **112-8** and **212-1** through **212-8** preferably include substantially the same architecture as LE **112-1** shown in FIG. 2. LE **112-1** preferably includes first and second, 4-input look up tables (4-LUTs) **140-1** and **140-2**. Such 4-LUTs are well understood by those skilled in the art. Each 4-LUT **140-1** and **140-2** are preferably driven by 4 of the 8 input lines **114-1**. First 4-LUT **140-1** drives a first flip-flop **142-1** which drives a first individual line of output lines **120-1**. A first bypass line **144-1** can be used to bypass first flip-flop **142-1**. Second 4-LUT **140-2** drives a second flip-flop **142-2** which drives a second individual line of output lines **120-1**. A second bypass line **144-2** can be used to bypass second flip-flop **142-2**. LE **112-1** illustrated in FIG. 2 may be simplified from an actual LE used in a LAB which may include additional or different components. An LE using additional components and which may be used in a method and device of the present invention is disclosed, for example, in D. Lewis et al., "The Stratix™ Routing and Logic Architecture" Altera Corporation, 101 Innovation Drive, San Jose, Calif. 95134, and Proceedings of the 2003 ACM/SIGDA Symposium on FPGAs, (available from ACM Press, ACM-ISBN 1-58113-651-X).

Referring again to FIG. 1, in LAB **110**, LAB lines **116** drive sets of input lines **114-1** through **114-8** and in LAB **210**, LAB lines **216** drive sets of input lines **214-1** through **214-8**. Preferably, as is understood by those skilled in the art, the 38 individual lines of LAB lines **116** and the 38 individual lines of LAB lines **216** are interconnected to each set of 8 individual input lines **114-1** through **114-8** and **214-1** through **214-8**, respectively, using multiplexers and/or programmable elements including RAMs, EPROMs, EEPROMs, fuses, anti-fuses or the like which can programmatically either connect or disconnect one line with a second intersecting line. In this way, any individual line of LAB lines **116** can drive any individual line of input lines **114-1** through **114-8** and any individual line of LAB lines **216** can drive any individual line of input lines **214-1** through **214-8**.

PLD portion **100** also includes a programmable swap multiplexer (MUX) **130** which is driven by output lines **120-1** through **120-8**. Preferably, swap MUX **130** includes two 16 line inputs. Thus, preferably, each individual line of

output lines **120-1** through **120-8** is fed directly into one of the two 16 line inputs of swap MUX **130** without passing through additional MUXs and/or programmable elements. It is contemplated, however, that each input of swap MUX **130** include fewer than 16 inputs and that a selection must be made of which output lines **120-1** through **120-8** drive swap MUX **130**. Such a selection can be made using MUXs and/or programmable elements as is understood in the art.

Also driving swap MUX **130** are a set of tap lines **224** which tap off of LAB lines **216** of LAB **210**. Preferably, there are 16 individual lines in the set of tap lines **224** to fully populate the second 16 line input of swap MUX **130**. There may also be greater or fewer than 16 lines in the set of tap lines **224**. Tap lines **224** connect to LAB lines **216** at tap line interconnect **226**. FIG. 3a is a detailed view of a preferred embodiment of tap line interconnect **226**. Individual LAB lines **216-1** through **216-38** of LAB lines **216** are illustrated as vertical lines (not all 38 individual LAB lines **216** are shown) and the 16 individual tap lines **224-1** through **224-16** of tap lines **224** are shown as horizontal lines (not all 16 individual tap lines **224** are shown). Preferably, 16 individual LAB lines **216-1** through **216-16** directly drive the 16 individual tap lines **224-1** through **224-16**, each individual LAB line **216-1** through **216-16** driving a single individual tap line **224-1** through **224-16**, respectively. Preferably, the interconnection between LAB lines **216** and tap lines **224** is fixed as shown in FIG. 2 and is not programmable. It is also considered, however, that LAB lines **216** be programmably interconnected with tap lines **224**. For example, a programmable interconnect could be placed at the intersection of each individual LAB line, or any subset of LAB lines **216**, and each individual tap line, or subset of tap lines **224**. In this way, which individual LAB line drives which individual tap line would be configurable.

Referring again to FIG. 1, LABs **110** and **210** also include sets of local lines **118** and **218**, respectively. Local lines **118** feed, along with LAB lines **116**, input lines **114-1** through **114-8** and local lines **218** feed, along with LAB lines **216**, input lines **214-1** through **214-8**. Preferably there are 16 individual lines in each set of local lines **118** and **218**, though it is considered that there be either greater or fewer such individual lines in each set of local lines **118** and **218**. Preferably, as understood in the art, interconnections between local lines **118** and input lines **114-1** through **114-8** are such that any individual line of local lines **118** can drive any individual line of input lines **114-1** through **114-8**. Swap MUX **130** drives local lines **118** and preferably includes a 16 line output. Thus, because as noted above, there are preferably 16 individual lines in local lines **118**, each individual line of local lines **118** is driven by one individual line of the output of swap MUX **130**.

Preferentially, as shown in FIGS. 2b and 3c, swap MUX **130** operates such that each output is generated from an independently programmed MUX driven by one or more local lines **120** and one or more neighboring LAB lines **224**. This detail is shown in FIG. 2b, where exactly one local and one lab line are joined with a 2:1 mux. In particular, FIG. 2b illustrates a series of 16, single bit 2 to 1 MUXs **130-1** through **130-16** (not all single bit 2 to 1 MUXs are shown in FIG. 2b) that make up swap MUX **130**. MUX **130-1** is driven by individual local line **120-1a**, a first individual line of local lines **120-1** driven by LE **112-1** of FIG. 1, and individual LAB line **224-1**, MUX **130-2** is driven by individual local line **120-1b**, as second individual line of local lines **120-1**, and individual LAB line **224-2** and MUX **130-16** is driven by individual local line **120-8b**, and LAB line **224-16**. Each single bit 2 to 1 MUX **130-1** through

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130-16' is configured with a single RAM bit R1 through R16, respectively. As such, a total of 16 RAM bits is necessary to configure full 16-bit swap MUX 130.

Alternatively, swap MUX 130 operates such that any individual line driving swap MUX 130 can drive an individual output line of swap MUX 130. That is, swap MUX 130 is able to select any individual line of output lines 120 and tap lines 224 to drive local lines 118, rather than being limited to selecting either all output lines 120 or all tap lines 224 to drive local lines 118. This functionally is illustrated in FIG. 3b, which shows output lines 120-1a' through 120-8b' and tap lines 224-1' through 224-16' driving local lines 118-1' through 118-16'. In FIG. 3b, individual lines 120-1a' and 120-1b' could each be one of the pair of lines of output lines 120-1' shown in FIG. 1. Similarly, individual lines 120-2a' and 120-2b' through 120-8b' (not all shown in FIG. 3b) could each be one of the pair of output lines 120-2' through 120-8', respectively. Output lines 120-1a' through 120-8b' and tap lines 224-1' through 224-16' intersect with local lines 118-1' through 118-16' at a plurality of programmable intersections 131'. As is understood in the art, each programmable intersection 131' can be programmed to either interconnect or not interconnect two lines crossing at the particular programmable intersection. Thus, because any of out output lines 120-1a' through 120-8b' and tap lines 224-1' through 224-16' can be interconnected to any local lines 118-1' through 118-16', any of output lines 120-1a' through 120-8b' and tap lines 224-1' through 224-16' can drive local lines 118-1' through 118-16'.

FIG. 3c illustrates the preferred configuration of swap MUX 130 in the notation of FIG. 3b. Specifically, individual lines 120-1a and 120-1b are each one of the pair of lines of output lines 120-1' shown in FIG. 1. Similarly, individual lines 120-2a and 120-2b through 120-8b (not all shown in FIG. 3b) are each one of the pair of output lines 120-2' through 120-8', respectively. Output lines 120-1a through 120-8b and tap lines 224-1 through 224-16 intersect with local lines 118-1 through 118-16 at a plurality of programmable intersections 131. Location of filled circles at intersections 131 indicate programmable connections. Skipovers at intersections of output lines 120-1a through 120-8b and tap lines 224-1 through 224-16 with local lines 118-1 through 118-16 indicate that connections cannot be made at these intersection. Thus, only one of two connections, either an output line or a tap line, with each local line can be made in the configuration of FIG. 3c.

As discussed above, LAB lines 116 of LAB 110 include 38 individual lines that provide input signals to LEs 112-1 through 112-8. In operation, if LAB 110 is configured with a function requiring 38 or fewer inputs, swap MUX 130 is preferably configured to pass the output signals on the sets of output lines 120-1 through 120-8 through to the set of local lines 118 such that, if necessary, these output signals can also drive LEs 112-1 through 112-8.

However, because LEs 112-1 through 112-8 each include 8 inputs, LAB 110 can be driven with up to 64 inputs. And, in some circumstances, it is desirable to drive one or more LABs, such as LAB 110, in a PLD with more than 38 inputs. Such circumstances may arise, for example, when LAB 110 is configured to carry out arithmetic functions having multiple bit inputs. When more than the 38 inputs provided by LAB lines 116 are needed to drive LAB 110, PLD portion 100 is able to provide such inputs. Specifically, in such circumstances, swap MUX 130 can be configured to pass to local lines 118 signals from tap lines 224. Because the set of tap lines 224 and the set of local lines 118 each include 16 individual lines, 16 additional input signals can be routed to

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LEs 112-1 through 112-8 of LAB 110, providing, in the example of FIG. 1, a maximum of 52 inputs to LAB 110.

PLD portion 100 additionally includes a second swap MUX 230, which, like swap MUX 130, preferably includes two, 16 line inputs and a single 16 line output. In manner analogous to that described above with respect to first swap MUX 130 and outputs 120-1 through 120-8, outputs 220-1 through 220-8 of LAB 210 drive a first input of second swap MUX 230. And in a manner analogous to that described above with respect to first swap MUX 130 and local lines 118, local lines 218 of LAB 210 are driven by the output of second swap MUX 230. Additionally, FIG. 1 includes a second set of tap lines 324 which are preferably interconnected to the LAB lines of a third LAB (not shown) in a manner analogous to that discussed above with respect to tap lines 224 and LAB lines 216. Tap lines 324 drive a second input of swap MUX 230. The output of second swap MUX 230 drives local lines 218 of LAB 210. In this way, LAB 210 can be driven by LAB lines from a third LAB (not shown). Thus, more than one LAB in a PLD can be driven by inputs that also drive another LAB.

As described above, in a method and apparatus of the present invention, in order to provide additional inputs to a first LAB, inputs from a second LAB may be used. This is likely to be acceptable in most situations because typically, functions carried out by a LAB do not use all of the LAB line inputs provided for the LAB. And, in a case where one LAB requires more inputs than are provided by its LAB lines, it is likely that an adjacent LAB will not require all of its LAB line inputs. Further, even if an adjacent LAB requires all, or nearly all, of its LAB lines, the PLD can likely be reconfigured to move a function into the adjacent LAB that does not require so many of its LAB lines.

FIG. 4 is a schematic diagram illustrating a second embodiment of a method and apparatus for providing additional inputs to a LAB. FIG. 4 shows a portion 300 of a PLD including a first, second and third LABs 310, 410 and 510, respectively. As with LABs 110 and 210 shown in FIG. 1, LABs 310, 410 and 510 each preferably include a plurality of LEs (not shown) for carrying out logic functions. LABs 310, 410 and 510 are driven from global lines (not shown) by sets of LAB lines 316, 416 and 516, respectively. Each set of LAB lines 316, 416 and 516 preferably include 38 individual lines, though any number of individual lines may be included. LABs 310, 410 and 510 also include sets local lines 318, 418 and 518, respectively, which each preferably include 16 individual lines, though any number of individual lines may be included. Both LAB lines 316, 416 and 516 and local lines 318, 418 and 518 can drive LEs on LABs 310, 410 and 510, respectively, through sets of inputs 314, 414 and 514, respectively. For clarity, in the schematic of FIG. 4, each set of inputs 314, 414 and 514 is indicated with a single arrow. It is to be understood, however, that each set of inputs 314, 414 and 514 can include a plurality of individual input lines which drive the LEs of LABs 310, 410 and 510, respectively, in the manner discussed above with respect to LABs 110 and 210. As discussed above with respect to LABs 110 and 210, preferably, any individual line of LAB lines 316, 416 and 516 and any individual local line of local lines 318, 418 and 518, respectively, can drive any LE of LABs 310, 410 and 510, respectively.

LEs of second LAB 410 drive a set of output lines 420 preferably in a manner similar to that described above and shown in FIG. 1 with respect to LEs 112-1 through 112-8 and output lines 120-1 through 120-8. Preferably, there are 16 individual lines in output lines 420, however any number of individual lines may be included in output lines 420.

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Output lines **420** are preferably broken into two subsets of branch lines **420a** and **420b**. In the example shown in FIG. 4, each subset of branch lines **420a** and **420b** include 8 individual lines. However, branch lines **420a** and **420b** can each include any number of lines such that the total number of individual lines in branch lines **420a** and **420b** is equal to or less than the number of individual lines in output lines **420**. Branch lines **420a** drive a first swap MUX **430a** and branch lines **420b** drive a second swap MUX **430b**. First MUX output lines **419a** and second MUX output lines **419b** each drive local lines **418**. In the example shown in FIG. 3a, first MUX output lines preferably include 8 individual lines **419a** and second MUX output lines **419b** include 8 individual lines. Preferably, the 8 individual lines of first MUX output lines **419a** drive directly into a first set of 8 individual lines of local lines **418** and the 8 individual lines of second MUX output lines **419b** drive directly into a second set of 8 individual lines of local lines **418**. Preferably, in this way, when a selection bit of first swap MUX **430a** is appropriately set, branch lines **420a** will drive the first set of 8 local lines **418** and when a selection bit of second swap MUX **430b** is appropriately set, branch lines **420b** will drive the second set of 8 local lines **418**.

In the embodiment of FIG. 4, LAB lines **316** can drive a set of first tap lines **324** and LAB lines **516** can drive a set of second tap lines **524**, respectively. Preferably, first tap lines **324** include 8 individual lines, but can also include greater or fewer individual lines. Also, preferably, second tap lines **524** include 8 individual lines, but can also include greater or fewer individual lines. The interconnection between LAB lines **316** and first set of tap lines **324** and the interconnection between LAB lines **516** and second set of tap lines **524** is preferably as discussed above and shown in FIG. 3a regarding LAB lines **216** and tap lines **224**.

First set of tap lines **324** drive an input of first swap MUX **430a** and second set of tap lines **524** drive an input of second swap MUX **430b**. Thus, depending on the state of a selection bit of swap MUX **430a**, either first set of tap lines **324** or branch lines **420a** will drive 8 individual lines of local lines **418**. And, depending on the state of a selection bit of swap MUX **430b**, either second set of tap lines **524** or branch lines **420b** will drive 8 individual lines of local lines **418**. If branch lines **420a** and **420b** drive local lines **418** through swap MUXs **430a** and **430b**, respectively, then local lines **418** will be entirely driven by LE output lines **420**. However, if LAB **410** requires more inputs from global lines than the 38 inputs that, in the embodiment shown in FIG. 3a, can be provided by LAB lines **414**, then a selection bit of swap MUX **430a** can be set to drive local lines **418** from LAB lines **316**. In this way, LAB **410** can be driven by inputs from LAB **310**. Further, if 8 additional inputs from LAB lines **316** are not enough to meet the requirements of a particular configuration of LAB **410**, then a selection bit of swap MUX **430b** can be set to drive local lines **418** with an additional 8 lines from LAB lines **516**. In this way, in the example shown in FIG. 4, the LEs of LAB **410** can be driven by up to an additional 16 inputs. Though LABs **310** and **510** are illustrated in FIG. 4 as adjacent to LAB **410**, it is not necessary that a LAB be able to receive inputs from LAB lines of other LABs that are only adjacent to the LAB. In particular, it is considered that LAB **310** be able to receive inputs from LAB lines associated with LABs that are not adjacent to LAB **310** or that are above and/or below LAB **310** in PLD **300**.

As discussed above with respect to swap MUX **130**, it is also considered that swap MUX **430a** can be configured such that any individual line of branch lines **420a** along with any individual line of tap lines **324** can drive any one of the

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individual lines of lines **419a** and swap MUX **430b** can be configured such that any individual line of branch lines **420b** along with any individual line of tap lines **524** can drive any one of the individual lines of lines **419b**.

As illustrated in FIG. 4, it is considered that more than one LAB of PLD **300** be able to receive input signals from LAB lines associated with other LABs. As shown in FIG. 4, a first input of a third swap MUX **530a** can receive inputs from third tap lines **534**, which can in turn be driven by LAB lines **516**. Swap MUX **530a** can also receive inputs from LE output lines **520** which are driven by a LEs in a fourth LAB (not shown). Third swap MUX **530a** drives MUX output lines **519**, which can drive the local lines (not shown) of a fourth LAB (not shown). In this way, third swap MUX **530a** provides the same function for a fourth LAB (not shown) that first swap MUX **430a** provides for LAB **410**. In particular, swap MUX **530a** allows LAB lines **516** to drive the local lines (not shown) of a fourth LAB (not shown) of PLD **300**.

FIG. 5 is a schematic diagram illustrating another embodiment of the present invention. FIG. 5 shows a portion **600** of a PLD including first, second and third LABs **610**, **710** and **810**. As with LABs **110** and **210** shown in FIG. 1, LABs **610**, **710** and **810** each preferably include a plurality of LEs (not shown) for carrying out logic functions. LABs **610**, **710** and **810** are driven from global lines (not shown) by sets of LAB lines **616**, **716** and **816**, respectively. Each set of LAB lines **616**, **716** and **816** preferably include 38 individual lines, though any number of individual lines may be included. LABs **610**, **710** and **810** also include sets local lines **618**, **718** and **818**, respectively, which each preferably include 16 individual lines, though any number of individual lines may be included. Both LAB lines **616**, **716** and **816** and local lines **618**, **718** and **818** can drive LEs on LABs **610**, **710** and **810**, respectively, through sets of inputs **614**, **714** and **814**, respectively. For clarity, in the schematic of FIG. 5, each set of inputs **614**, **714** and **814** is indicated with a single arrow. It is to be understood, however, that each set of inputs **614**, **714** and **814** can include a plurality of individual input lines which drive the LEs of LABs **610**, **710** and **810**, respectively, in the manner discussed above with respect to LABs **110** and **210**. As discussed above with respect to LABs **110** and **210**, preferably, any individual line of LAB lines **616**, **716** and **816** and any individual local line of local lines **618**, **718** and **818**, respectively, can drive an LE of LABs **610**, **710** and **810**, respectively.

LEs of second LAB **710** drive a set of output lines **720** preferably in a manner similar to that described above and shown in FIG. 1 with respect to LEs **112-1** through **112-8** and output lines **120-1** through **120-8**. Preferably, there are 16 individual lines in output lines **720**, however any number of individual lines may be included in output lines **720**. In the example shown in FIG. 4, output lines **720** drive one input of swap MUX **730**. Output lines **719** of swap MUX **730** preferably drive directly into local lines **718**. Thus, by appropriately setting a selection bit (not shown) of swap MUX **730**, output lines **720** can drive local lines **718**.

LAB portion **600** also includes first tap lines **624** and a second tap lines **824**. First tap lines can be driven by LAB lines **616** and second tap lines can be driven by LAB lines **816**. Preferably, first tap lines **624** include 16 individual lines, but can also include greater or fewer individual lines. Also, preferably, second tap lines **824** include 16 individual lines, but can also include greater or fewer individual lines. The interconnection between LAB lines **616** and first tap lines **624** and the interconnection between LAB lines **816**

and second tap lines **824** is preferably as discussed above and shown in FIG. 1 regarding LAB lines **216** and tap lines **224**.

As shown in FIG. 4, swap MUX **730** is preferably a 3:1 MUX and first tap lines **624** and second tap lines **824** each drive an input to swap MUX **730**. Thus, by appropriately setting a selection bit (not shown) of swap MUX **730**, either first tap lines **624** or second tap lines **824** can drive local lines **718** through swap MUX output lines **719**. In this way, if LAB **710** requires more than the 38 inputs provided by LAB lines **716**, either 16 additional individual lines of LAB lines **616** or 16 additional individual lines of LAB lines **816** can be used to drive the LEs of LAB **719** through swap MUX **730**. As discussed above with respect to swap MUX **130**, it is also considered that any individual line of tap lines **624** along with any individual line of output lines **720** and any individual line of tap lines **824** can drive any individual line of output lines **719**.

Various modifications to the preferred embodiments can be made without departing from the spirit and scope of the invention. Thus, the foregoing description is not intended to limit the invention which is described in the appended claims.

What is claimed as new and desired to be protected by Letters Patent of the United States is:

1. A programmable logic device (PLD) including:
 - at least first and second logic array blocks (LABs);
 - a plurality of first signal lines capable of driving the second LAB;
 - a plurality of output lines driven by the first LAB; and
 - a first swap multiplexer (MUX) having a first selectable input capable of being driven directly by at least one of the plurality of output lines and a second selectable input capable of being directly driven at least one of the plurality of the first signal lines, and an output capable of driving the at least first LAB.
2. The PLD of claim 1 wherein:
 - the first LAB includes a first plurality of logic elements (LEs) and the second LAB includes a second plurality of LEs;
 - at least one of the plurality of output lines is driven by at least one of the first plurality of LEs;
 - at least one of the plurality of the first signal lines is capable of driving at least one of the second plurality of LEs; and
 - the output of the first swap MUX is capable of driving at least one of the first plurality of LEs.
3. The PLD of claim 2 wherein:
 - the first LAB includes a plurality of local lines at least one of which drives at least one of the first plurality of LEs; and
 - the output of the first swap MUX drives at least one of the plurality of local lines.
4. The PLD of claim 3 further including at least one additional signal line for exclusively driving the second LAB.
5. The PLD of claim 4 wherein the plurality of first signal lines include a plurality of LAB lines which drive the second LAB and a plurality of tap lines at least one of which is interconnected with at least one of the plurality of LAB lines, at least one of the plurality of tap lines driving the first selectable input of first swap MUX.
6. The PLD of claim 5 wherein the interconnection between the at least one LAB line and at least one tap line is fixed.
7. The PLD of claim 6 further including at least a third LAB and a plurality of second signal lines capable of driving

the third LAB wherein the first swap MUX includes a third selectable input and at least one of the second signal lines drives the third selectable input.

8. The PLD of claim 6 further including:
 - at least a third LAB and a plurality of second signal lines capable of driving the third LAB;
 - a second swap MUX having a first selectable input and second selectable input the first selectable input capable of being driven by at least one of the second signal lines; and
 - wherein the plurality of tap lines include a first set of tap lines and a second set of tap lines, at least one of the first set of tap lines capable of driving the first selectable input of the first swap MUX and at least one of the second set of tap lines capable of driving the second selectable input of the second swap MUX.
9. A programmable logic device (PLD) including:
 - at least first and second logic array blocks (LABs), the first LAB including a first plurality of logic elements (LEs) and the second LAB including a second plurality of LEs;
 - a plurality of first signal lines capable of driving at least one of the second plurality of LEs;
 - a plurality of output lines driven by at least one of the first plurality of LEs; and
 - a first swap multiplexer (MUX) having a first selectable input capable of being driven directly by at least one of the plurality of output lines and a second selectable input capable of being directly driven by at least one of the plurality of first signal lines, and an output capable of driving at least one of the first plurality of LEs.
10. The PLD of claim 9 wherein:
 - the first LAB includes a plurality of local lines which drive the first plurality of LEs; and
 - the output of the first swap MUX drives at least one of the plurality of local lines.
11. The PLD of claim 10 wherein the plurality of first signal lines include a plurality of LAB lines at least one of which drives the second LAB and a plurality of tap lines at least one of which is interconnected with at least one of the LAB lines, at least one of the tap lines driving the first selectable input of the first swap MUX.
12. The PLD of claim 11 further including at least a third LAB and a plurality of second signal lines capable of driving the third LAB wherein the first swap MUX includes a third selectable input and at least one of the second signal lines drives the third selectable input.
13. The PLD of claim 11 further including:
 - at least a third LAB and a plurality of second signal lines capable of driving the third LAB;
 - a second swap MUX having a first selectable input and a second selectable input the first selectable input capable of being driven by at least one of the second signal lines; and
 - wherein the plurality of tap lines include a first set of tap lines and a second set of tap lines, at least one of the first set of tap lines capable of driving the first selectable input of the first swap MUX and at least one of the second set of tap lines capable of driving the second selectable input of the second swap MUX.
14. A method of driving logic array blocks (LABs) in a programmable logic device (PLD) including:
 - providing at least first and second LABs in the PLD;
 - driving the second LAB with at least one of a first plurality of signal lines;
 - driving at least one of a plurality of output lines with the first LAB;

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directly driving a first selectable input of a first swap multiplexer (MUX) with at least one of the plurality of output lines;

directly driving a second selectable input of the first swap MUX with at least one of the plurality of first signal lines; and

driving at least the first LAB with an output of the first swap MUX.

15. The method of claim **14** further including:

providing a first plurality of logic elements (LEs) in the first LAB;

providing a second plurality of LEs in the second LAB; driving at least one of the plurality of output lines with at least one of the first plurality of LEs; and

driving at least one of the second plurality of LEs with at least one of the plurality of first signal lines.

16. The method of claim **15** including:

providing a plurality of local lines in the first LAB;

driving at least one of the first plurality of LEs with at least one of the plurality of local lines; and

driving at least one of the plurality of local lines with the output of the first swap MUX.

17. The method of claim **16** further including providing at least one additional signal line for exclusively driving the second LAB.

18. The method of claim **17** further including:

providing a plurality of LAB lines and a plurality of tap lines in the plurality of first signal lines;

driving the second LAB with at least one of the plurality of LAB lines; and

interconnecting at least one of the plurality of tap lines with at least one of the plurality of LAB lines;

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driving the first selectable input of the first swap MUX with at least one of the plurality of tap lines.

19. The method of claim **18** further including fixing the interconnection between the at least one of the plurality of LAB lines and the at least one of the plurality of tap lines.

20. The method of claim **19** further including providing at least a third LAB and a plurality of second signal lines;

driving the at least third LAB with at least one of the plurality of second signal lines

providing a third selectable input in the first swap MUX; and

driving the third selectable input with at least one of the plurality of second signal lines.

21. The method of claim **19** further including:

providing at least a third LAB and a plurality of second signal lines;

driving the third lab with at least one of the plurality of second signal lines;

providing a second swap MUX having a first selectable input and a second selectable input;

driving the first selectable input with at least one of the plurality of second signal lines;

including in the plurality of tap lines a first set of tap lines and a second set of tap lines;

driving the first selectable input of the first swap MUX with at least one of the first set of tap lines; and

driving the second selectable input of the second swap MUX with at least one of the second set of tap lines.

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